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THE USE OF CHEMICALS AS SOIL ADDITIVES. AGRICULTURAL CHEMICALS TECHNOLOGY, NUMBER 3.

OHIO STATE UNIV., COLUMBUS, CENTER FOR VOC. EDUC.

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THE PURPOSE OF THIS GUIDE IS TO ASSIST TEACHERS IN PREPARING POST-SECONDARY STUDENTS FOR AGRICULTURAL CHEMICAL OCCUPATIONS. IT IS ONE OF A SERIES OF MODULES DEVELOPED BY A NATIONAL TASK FORCE ON THE BASIS OF STATE STUDY DATA. SECTIONS ARE (1) PHYSICAL AND CHEMICAL ALTERATION OF SOIL WITH CHEMICAL ADDITIVES, (2) TERMINOLOGY AND COMPUTATIONS, (3) LAWS, REGULATIONS, AND CONTROLS, (4) SOIL STRUCTURE AND COMPOSITION, (5) CHEMICALS AS SOIL ADDITIVES, AND (6) SOIL ADDITIVE PRINCIPLES AND CONCEPTS. IN ADDITION TO SUGGESTIONS FOR INTRODUCING THE MODULE, OBJECTIVES, SUBJECT MATTER CONTENT, TEACHING-LEARNING ACTIVITIES, AND INSTRUCTIONAL MATERIALS AND REFERENCES ARE SUGGESTED FOR EACH SECTION. TEACHERS NEED A BACKGROUND IN AGRICULTURAL CHEMICALS, AND STUDENTS SHOULD HAVE POST-HIGH SCHOOL STATUS, AN APTITUDE IN CHEMISTRY, AND AN OCCUPATIONAL GOAL IN AGRICULTURAL CHEMICALS. THE MATERIAL IS DESIGNED FOR 12 HOURS OF CLASS INSTRUCTION, 36 HOURS OF LABORATORY EXPERIENCE, AND 80 HOURS OF OCCUPATIONAL EXPERIENCE. THIS DOCUMENT IS AVAILABLE FOR A LIMITED PERIOD FOR $6.75 PER SET (VT 001 214 - 001 222) FROM THE CENTER FOR VOCATIONAL AND TECHNICAL EDUCATION, THE OHIO STATE UNIVERSITY, 980 KINNEAR ROAD, COLUMBUS, OHIO 43212. (JM)

THE USE OF CHEMICALS AS SOIL ADDITIVES

AGRICULTURAL CHEMICALS TECHNOLOGY
No. 3

The Center for Research and Leadership Development
in Vocational and Technical Education

The Ohio State University
980 Kinnear Road
Columbus, Ohio 43212

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M E M O R A N D U M

TO: The ERIC Clearinghouse on Vocational and Technical Education
The Ohio State University
980 Kinnear Road
Columbus, Ohio 43212

FROM: (Person) James W. Hensel (Agency) The Center for Vocational and Technical Education

(Address) 980 Kinnear Road, Columbus, Ohio 43212

DATE: August 7, 1967

RE: (Author, Title, Publisher, Date) **Module No. 3, "The Use of Chemicals as Soil Additives," The Center for Vocational and Technical Education, December, 1965.**

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Uses of Material Instructor course planning
Users of Material Teachers

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Student Selection Criteria Post high school level, aptitude in chemistry, high school prerequisite, goal in the agricultural chemicals industry.
Time Allotment Estimated time listed in module. (P)

Supplemental Media --
Necessary x (Check Which)
Desirable

Describe Suggested references given in module. (P)

Source (agency)
(address)

This publication is a portion of the course material written in Agricultural Chemicals Technology. To be understood fully, the complete set of materials should be considered in context. It is recommended that the following order be observed for a logical teaching sequence:

#1 - The Use of Chemicals as Fertilizers

#2 - The Use of Chemicals as Insecticides - Plants

#3 - The Use of Chemicals as Soil Additives

#4 - The Use of Chemicals as Fungicides, Bactericides and Nematocides

#5 - The Use of Chemicals to Control Field Rodents and Other Predators

#6 - The Use of Chemicals as Herbicides

#7 - The Use of Chemicals in the Field of Farm Animal Health (Nutrition, Entomology, Pathology)

#8 - The Use of Chemicals as Plant Regulators

TABLE OF CONTENTS

THE USE OF CHEMICALS AS SOIL ADDITIVES*

Major Teaching Objective

To develop the understanding and abilities needed to be employed as an agricultural chemicals technician by a firm which manufactures, distributes, or sells chemicals for use as soil additives.

Subsidiary Objectives

1. To develop an interest in and an appreciation of the role which chemicals can play in the production of farm crops and in the ability of man to modify various physical and chemical characteristics of the soil through the use of chemical soil additives.

2. To gain an understanding of the principles of soil physics and chemistry, plant physiology and nutrition, and plant-soil-moisture relations important to the study and use of soil additives by technicians in order to modify soil characteristics.

Suggested Time Allotment

At school		
Class instruction	12 hours	
Laboratory instruction	36 hours	
Total at school		48 hours
Occupational experience		80 hours
Total for the Module		128 hours

Suggestions for Introducing the Module

Note: In contrast to the study of fertilizers, where the concern primarily has to do with supplying plant nutrients, the study of

*As used in this course of study, soil additives are materials added to the soil to improve plant growth by indirect action and include the following: soil acidifiers, "sodium replacing" compounds, synthetic soil conditioners, and soil anti-crustants.

soil additives has to do with problems associated with acid, alkaline, and saline soils, and with soil structure. At the beginning of this study, it should be pointed out that:

1. Materials other than those considered in this course outline are available for use as soil additives. Included in such materials are various organic substances, some synthetics, and combinations of various earthen materials.

2. Some chemicals used as soil additives are also often used as fertilizers.

3. Alternative ways can be used to change physical and chemical characteristics of the soil. Among these are washing and draining the soil, sub-soiling or otherwise mechanically working the soil, and using mulches.

The following suggestions may be helpful for introducing this module.

1. Demonstrate by using pots or flats of various soils and indicator plants (with appropriate control soils and plants) the effects of soil additives upon soils whose chemical and physical properties have been impaired for normal plant growth. Make no attempt to study soil additives, soil problems or responses in detail at this time.

2. Make a local survey to determine:

   (a) The extent to which acidity, alkalinity, salinity, impermeability, and crustation are problems. Contact can be made with such persons and groups as the Soil Conservation Service, county agent or farm advisor, University Cooperative Extension Service, the State Agricultural Experiment Station, local agricultural chemicals dealers, farmers, soils laboratories, crop associations, and college and university crops and soils department.

   (b) The practices that are being used and the results which are being secured.

   (c) The results which are secured both in terms of immediate returns through the use of soil additives and also in terms of long-range changes occurring in the soil.

   (d) The skills, abilities, and understandings which agricultural chemical technicians need for employment in occupational endeavors which have to do with the use of soil additives. It probably will be possible

to categorize the findings under one of the following subheadings:

1) To develop an interest in and an appreciation and understanding of man's use of chemicals to attempt to alter the chemical and physical properties of the soil.

2) To become familiar with and gain a knowledge of federal, state, and local laws, regulations, and controls affecting the sale and use of chemicals for use as soil additives.

3) To learn to recognize and identify various soil conditions where the soil structure or composition has been impaired, damaged, or altered and to understand the causative factors of this impairment.

4) To become knowledgeable regarding various chemicals which are commonly used as soil additives.

5) To gain a knowledge and understanding of the principles, practices, and concepts underlying the use of chemicals as soil additives.

6) To gain an understanding and knowledge of approved practices in using chemicals as soil additives and also to develop the effective ability to apply chemicals upon specific soils for improvement.

7) To develop the ability to use important terms, nomenclature, definitions, tables, charts, and guides commonly used and also to develop the ability to make important computations, conversions, calculations and measurements which are commonly used by technical workers in the field.

8) To acquire and practice the skills and ability to safely and properly handle, transport, store or apply soil additives using the proper techniques, methods, machinery, and equipment while safeguarding the rights of others.

3. As a follow-up to 2(d) above, and as an introduction to the course, the following outline should be given to the students. Orientation will be necessary as to lectures, reading assignments, texts and references, laboratory exercises, examinations, experience programs, and educational outcomes.

SUGGESTED COURSE OUTLINE

The Use of Chemicals as Soil Additives — Course No.__________

Instructor__________ Texts & References__________

Lecture	Reading Assignment	Laboratory Assignment	Understandings, Skills & Abilities to be Developed
1. a) Orientation & explanation of course. b) Man's use of chemicals to attempt to alter the chemical & physical properties of the soil.			
2. Terms & computations used by technical workers in using soil additives.			
3. Impaired soil conditions & causative factors.			
4. Chemicals which are commonly used as soil additives.			
5. Principles, practices, & concepts underlying the use of chemicals as soil additives.			
6. Approved practices in using chemicals as soil additives.			
7. Federal, State, & Local laws, regulations, and controls.			
8. The safe handling & application of soil additives.			

4. The following statements from the Fact Book of U. S. Agriculture, Revised January, 1965, may be helpful for motivational purposes:

   The farmer is a buyer, a seller, a taxpayer, a consumer, a manufacturer, a businessman, and a worker. He is never one of these alone. Here is a portrait of a "statistical" farmer in 1963:

   As a buyer, he spent $8,200 for his business needs.
   As a seller, he receives $10,300 for his farm products.
   As a manufacturer, his "factory" was valued at $51,500.

   In 1940 the "statistical" farmer spent $1,000 for business expenses and received less than $1,500 for his farm goods. His "factory" was valued at less than $6,200.

   In the early 1960's farmers used enough steel products each year to make almost five million compact cars, enough rubber to put tires on more than six million cars, enough electricity to power the six New England States.

   They used the equivalent of 15 billion gallons of crude oil, more than any other single industry uses, and they spent $1.5 billion for fertilizer and lime.

   Total resources used in agriculture including land, labor, machinery, supplies, and other inputs, have increased only 24 per cent since 1910. But farm production has doubled through complex changes that include the use of about five times the mechanical power and machinery; 11 times the amount of fertilizer and lime: . . .

Agricultural chemicals technology, the application of new techniques and innovations in agricultural chemicals, continually strengthens our nation and increases its status among all lands and peoples of the world. As technology in agricultural chemicals increases, the need for qualified people in agricultural chemicals increases, the need for qualified people in agricultural chemicals to serve on the technical level will also show rapid growth.

It is most difficult to determine how many agricultural chemical technologists are needed, either at the present time or in the near future, for several reasons. Among them are:

1) The title of technician is applied to varying types of jobs.

2) The lack of job description information regarding off-farm agricultural occupations.

(It is suggested that the teacher refer to state and local studies of off-farm agricultural occupations for the number of technical workers needed in agricultural chemicals.)

5. Divide the class into interest groups for intensive study of the following occupations, as they pertain to soil additives:

   Agricultural Chemical Product Salesman

   Agricultural Chemical Product Serviceman

   Agricultural Chemical Equipment Salesman

   Agricultural Chemical Equipment Serviceman

   Agricultural Chemical Production & Control Technician

   Agricultural Chemicals Fieldman

   Farm Management Consultant

   Agricultural Chemicals Technician

   Agricultural Chemicals Specialist

   Agricultural Chemicals Applicator

   The following topical outline may be used for committee reports to the class:

   A. Job duties

   B. Requirements for entering

   C. Promotional outlook

   D. Pay and skill level

Competencies to be Developed

I. To develop an interest in and an appreciation and understanding of man's use of chemicals to alter the chemical and physical properties of the soil through the use of chemical additives.

Teacher Preparation

Subject Matter Content

Note: Review relevant aspects of soil physics and chemistry, plant physiology and nutrition, and plant-soil-moisture relations as they are related to the use of soil additives. Examine what man attempts to accomplish through the use of soil additives, what the chemical additives industry is like, and some of the problems commonly encountered in attempting to alter physical and chemical properties of the soil through the use of chemical additives.

1. Examination of the Problem

   (Prevention - Minor Treatment - Maintenance - Major Reclamation)

   a. Statement of the problem -- the need to be concerned about soil dynamics and the case of soil additives. Attempts to avert the consequences of soil acidity, alkalinity, or salinity; impermeability; and crustation.

      According to Bower and Firman an estimated one-fourth of our twenty-nine million acres of irrigated land and less extensive acreages of non-irrigated crop and pasture lands are soils that have been harmed by soluble salts consisting of sodium, calcium, magnesium, and others. Salt affected soils occur primarily in an arid or semiarid climate. Often, the problem occurs in irrigated land. Saline soils, which may occur naturally, contain excessive amounts of soluble salts. Often, these soils are caused by farmers who have failed to provide adequate drainage to care for additional amounts of water and the leaching needed to prevent accumulation of soluble salts. This often causes the water table to move upward to within 5 or 6 feet of the surface resulting in the accumulation of soluble salts in the root zones. Alkali soils, which often contain excessive

amounts of absorbed sodium, are also caused by the upward movement of water. The absorbed sodium must be replaced with calcium or magnesium along with some improvement of soil structure if the effects of such conditions as "black alkali" are to be controlled.

2. Possible course of action

   a. General methods of altering the physical and chemical properties of the soil

      1) Use of soil additives - chemical

      2) Tillage practices

      3) Irrigation and drainage

      4) Use of crop residues, manures

      5) Use of other amendments

3. Review of pertinent specialties

   a. Soil physics and chemistry

   b. Plant physiology and nutrition

   c. Plant - soil - moisture relations

4. Altering the physical and chemical properties of the soil through the use of soil additives

   a. Kinds of chemicals available

      1) Chemicals for changing acidity of the soil

      2) Chemicals for changing alkalinity of the soil

      3) Chemicals for changing salinity of the soil

      4) Chemicals for improving permeability of the soil

      5) Chemicals for preventing crustation of the soil

   b. Examples of well-known improvement programs and the results obtained. (Cite local examples if possible.)

      1) Man has attempted to correct saline and alkali soils with a combination of adequate drainage and chemical amendments. Among the chemical amendments for replacing absorbed sodium are:

         a) Calcium chloride and gypsum

         b) Limestone

c) Sulfuric acid

d) Sulfur

e) Iron

f) Aluminum sulfate

c. Major determinations required in a soil improvement program

1) Kind of additive to use

2) Time to use additive

3) Placement of additive

4) Amounts of additive to use

5) Method of application to use

6) Costs of using additives

7) Dangers and precautions

d. What results can be expected from the use of soil additives

1) Soil response (pH, infiltration rate, drainage, aeration, exchange capacity)

e. The importance of using soil additives

1) Economic

2) Managerial

3) Cultural

4) Ethnic relationships

f. Problems encountered in using chemicals as soil additives

1) Problems with acid soils

2) Problems with nonsaline-alkali soils

3) Problems with saline soils

4) Problems with saline-alkali soils

5) Problems with tight soils, or those having low permeability rates

6) Problems with crusted soils

5. The Soil Additives Industry

a. Historical Background

Man's use of chemicals to attempt to alter the chemical and physical properties of the soil extends back many centuries. According to Millar a Greek historian, Xenophon (430 - 355 B.C.), mentions plowing under green plants as a means of soil enrichment. The use of lime as a soil amendment was among some agricultural practices advocated in Roman books written by Columella (first century A.D.).

With the fall of the Roman Empire and the onset of the Middle Ages, little progress was made in the use of chemicals as soil amendments. There is some evidence that lime in the form of chalk and marl was used in England and France as early as the sixteenth century. Jethro Tull, an Oxford man, theorized in 1731 that all plants live on the same food, namely, fine soil particles.

Farmers who had used lime in Europe introduced this practice into colonial America. The establishment of Agricultural Experiment Stations in the middle of the 19th century led to recommendations for using lime on acid soils. The use of lime has grown steadily in the United States until in 1959, as reported by the Census (1959), about one out of eight farms reported the use of lime and liming materials.

Sizeable increases have occurred during the last two decades in the number of farms reporting and the quantity of lime and liming materials used in the United States.

Census year	Farms reporting: Number of farms	Farms reporting: Per cent increase over preceding census	Tons of lime and liming materials used: Total	Tons of lime and liming materials used: Per cent increase over preceding census
1959	453,954	-12.8	19,161,340	11.1
1954	520,445	-35.8	17,276,170	*102.9
1949	811,222	71.9	NA	NA
1939	471,807	NA	8,516,107	NA

*Per cent increase over 1939

b. Present status and situation

The maps on page 327 of the U. S. Census for Agriculture show that the use of lime is concentrated largely in the Northern States and South Atlantic States.

(2 maps on p. 327 of the Census.)

c. Recent developments and future trends

1) Acid soils

2) Saline soils

3) Nonsaline-alkali soils

4) Saline-alkali soils

5) Other soil problems, e.g., compacted, impaired soil structure, crust formation

6) Research

a) Old field experiments (Illinois, Pennsylvania, Ohio)

b) Present research

c) Projected research

Suggested Teaching-Learning Activities

1. Invite a local representative of a firm which retails chemical soil additives to speak to the class on the effects of controlling the chemical and physical properties of the soil through the use of soil additives.

2. Have the class conduct an area survey to determine job opportunities in the manufacture or sale of soil additives.

3. Arrange a field trip to a firm retailing agricultural chemicals for use as soil additives. It may be possible to visit a local processing plant as well.

4. Discuss and develop with the class a list of specific skills which they feel would be needed by a technical worker in soil additives. Discuss these with firms in the community or region and revise them as necessary.

5. Divide the class into discussion groups. Give each group a soil sample and suggest a crop. Suggest also a theory which would relate to experiments such as those conducted by Van Helmont and Jethro Tull.

6. Show the film, "The Soil is Good."

7. With demonstrations, show the effect acidity and/or alkalinity can have on the response of local crops. For example, barley seeds planted in quart jars containing the same loam soil but

with different artificially introduced pH ranges from pH 5 to 10. This range can be obtained by adding NaOH (lye) to the soil. Black alkali, soil pH tolerance and soil crustation effects on seedlings can be vividly illustrated.

8. Select one or more experiments that were conducted in the early days of American agriculture. Have the students plan and conduct these experiments on a test plot. A guide sheet for conducting experiments should be provided by the teacher.

9. Discuss where to go for "expert" help with difficult field problems.

Suggested Instructional Materials and References

1. Instructional Materials

   a. Film - "The Soil is Good"

      Available from - Minneapolis-Moline Co., Minneapolis, Minnesota

      Cost - Transportation one way

   b. Selected brochures from local firms and pamphlets available at state extension offices

   c. Soil samples and plant seeds or specimens

2. References

   a. Soil Fertility, pages 1-10, C. E. Millar, John Wiley & Sons, Inc., New York, New York.

   b. U. S. Census of Agriculture, Vol. II, General Report, Chapter IV, pages 325-327.

   c. Soils, Yearbook of Agriculture, 1957.

II. To develop the ability to use important terms, nomenclature, definitions, tables, charts, and guides which are used in the field and also to develop the ability to perform important computations, conversions, calculations, and measurements which are commonly used by technical workers.

Teacher Preparation

Subject Matter Content

Note: This unit is presented here at an early point in the study guide in order that the instructor may review it and make plans to make use of the data and information provided for herein throughout the remainder of the course. It is not intended that the unit will be taught as a separate competency, as are the other major units of the course, but that the material provided for here will be integrated as appropriate throughout the rest of the study. The purpose of this section then is to provide for the pulling together in one place a core of information appropriate to the course.

It will be necessary for the instructor to gather information and materials from various sources including the ones recommended in this unit.

Guidelines in the form of an outline for use in summarizing data gathered pertinent to this section are presented.

(Data presented in this section of the study guide for the course "The Use of Chemicals as Insecticides" may be useful for a review.)

SECTION ONE - General Information

THE STUDENT WILL NEED TO BE ABLE TO:

1. Make use of words, terms, and phrases appropriate to the subject matter of the course. A Glossary of Terms will facilitate this usage.

2. Perform measurements, conversions, computations, and calculations commonly used by technical workers in the field. Tables containing units of measurement and tables of equivalents of units will be useful.

   a. Tables of measurement

      -- Linear measure - length

-- Square measure - area

-- Cubic measure - volume

-- Liquid measure - capacity

-- Dry measure - capacity

-- Weight measure

-- Temperature measure

-- Time measure

-- Other

b. Tables of convenient equivalents

-- Equivalent volumes - liquid measure

-- Equivalent volumes - dry measure

-- Equivalent weight/volume - liquid

-- Equivalent weight/volume - dry

-- Equivalent lengths

-- Equivalent areas

-- Equivalent weights

-- Equivalent temperatures

-- Equivalent (other)

SECTION TWO - Information Regarding Agricultural Chemicals

THE STUDENT WILL NEED TO MAKE USE OF:

1. A table which lists the common name, active ingredient, and trade name(s) of chemicals studied in the course.

2. An alphabetical listing of chemicals commonly used in the field. Information such as the trade name, name of major producer, composition, formulation, and recommended use.

3. A listing of chemical materials according to the general use.

4. Compatability charts and tables

   a. Phytotoxicity (with plants)

   b. Chemicals (with other chemicals)

   c. Physical (with other chemicals)

5. Toxicity tables providing LD and LC values (both oral and dermal, acute and chronic) of chemicals studied in the course.

6. Tolerance limitations imposed by F.D.A. upon residues applicable to the subject matter of the course (i.e., herbicides, insecticides, fungicides, etc.).

What is one part per million?

Most lay people have no conception of what constitutes one part per million residue on crops. The following examples may help you make this interpretation for them:

1. One inch is one part per million in 16 miles.
2. A postage stamp is one part per million of the weight of a person.
3. A one gram needle in a one ton hay stack is 1 ppm.
4. One part per million is one minute in two years.
5. Lay your hand on the ground and it covers 5 ppm of an acre.
6. If one pound of a chemical lands on an acre of alfalfa the hay has 500 ppm. One ounce of a chemical would impart 31 ppm.
7. A teaspoon of material on an acre of alfalfa would impart 5 ppm.
8. One teaspoon of DDT drifting onto 5 acres of alfalfa puts 1 ppm in the hay, and the Federal Law says that the hay must contain none.

(Source--Western Crops and Farm Management)

SECTION THREE - Preparation of Chemicals for Use

THE STUDENT WILL NEED TO BE ABLE TO:

1. Determine whether or not materials prepared and commercially packaged can be applied directly from the container.

2. Determine the total amount(s) of active ingredient(s) contained in a chemical mixture. Mixtures may vary according to weight, volume, concentration, and formulation.

3. Make a determination of the amounts, by weight or by volume, of chemical materials of various levels of concentration to use in order to prepare a given quantity of mixture that will meet recommended or specified dosage or concentration levels. (Weights or volumes of solid or liquid chemicals required to prepare a given quantity of material of different dilutions.)

4. Interpret tables and recommendations for "concentrate" spraying.

SECTION FOUR - Preparation Necessary to Secure Specified or Recommended Application Rates

THE STUDENT WILL NEED TO BE ABLE TO:

1. Compute the area of various plots of land. These plots will vary in size, shape, topography, and planting.

   a. Determine acreage of row planting which vary according to spacing.

   b. Determine total acreage of plots.

2. Determine the speed of a vehicle traveling on the land. (In miles per hour and feet per minute.)

3. Three variables affect the application rate of agricultural chemicals secured in the field - the speed of travel, the effective width of the device applying the chemical, and the total material delivered per unit of time. If two of these variables are known, calculate the other in order to secure a specific application rate.

   a. Calibrate sprayers, dusters, or metering devices to secure specific delivery rates.

   b. Compute the length of boom, number of outlets, or width of opening to secure specific widths.

   c. Calibrate ground speed to secure specific rate of forward travel.

4. Use tables of "Rate of Equivalents."

   Example: 1 ounce per square foot = 2722.5 pounds per acre

5. Calculate the quantity applied per length of row (on various spacings) which will be equivalent to a specific application per acre.

6. Consider the effect of particle size on drift and deposit. (Prepare spray drift and deposit table.)

7. Use aerial maps to determine acreages by measurement, by instrument, and by approximation overlay.

SECTION FIVE - Information Relative to Diagnosis and Prescription

THE STUDENT WILL NEED TO MAKE USE OF:

1. Tables, charts, and guides which summarize situations encountered in agricultural production in which the use of chemicals is appropriate. Materials to use and methods of application are suggested.

Examples of form used:

Plant or Soil	Pest, Disease or Condition	Causative Agent or Factor	When to Treat	What Material to Use
Alfalfa to be planted on clay loam	Black alkali and high pH	Soluble Sodium Salts	Before planting	Sulfur

Active Ingredient Per Acre	Formulation	Amount Concentration Req'd Per Acre	Method of Application	Remarks
NA	Fines	3000 lbs/A	Broadcast and work into soil	Leach, using at least 2 acre feet of water

2. Graphs, charts, tables, and other illustrative materials available and supportive of the unit under consideration.

Examples:

a. Graphical relationships

-- time versus residue levels

-- rates of application versus levels of effectiveness

-- levels of concentration versus levels of effectiveness

-- stage of development or growth versus effectiveness of chemical control, etc.

SECTION SIX - Sources of Information

Soil Fertility, Millar, C. E., John Wiley & Sons, Inc., New York, New York

U. S. Census of Agriculture, Vol. II, General Report, Chapter IV

Soils, Yearbook of Agriculture, 1957

Open Door to Plenty, National Agricultural Chemical Association, 1145 19th Street, N. W., Washington 6, D.C.

Soil Science, Millar, Turk, John Wiley & Sons, Inc., New York, N. Y.

The Nature and Properties of Soils, 6th Edition, Buckman & Brady, The MacMillan Company, New York, New York

Soil Conditions and Plant Growth, 9th Edition, Russel. John Wiley & Sons, Inc., New York, New York

Soil Management for Conservation & Production, Cook, John Wiley & Sons, Inc., New York, New York

Irrigated Soils, Thorne and Peterson, Blakeston, 1954, Philadelphia and Toronto

Diagnosis and Improvement of Saline and Alkali-Soils, U. S. Salinity Laboratory Staff, U.S.D.A. Handbook No. 60

Modification of Some Physical Characteristics of Soils With VAMA, Ferric Sulfate, and Triphenylsulfanium Chloride, Pugh, A. L., et al. Agran. J. 52:399-402, 1960

Changes in Soil Compressibility Associated With Polyelectrolyte Treatment, Taylor, H. M., and Vomocil, J. A. Proceed. Soil Science Society America, Vol. 23:181-183, 1959

III. <u>To become familiar with and gain a knowledge of federal, state, and local laws, regulations, and controls affecting the sale and use of chemicals as soil additives.</u>

Teacher Preparation

Subject Matter Content

Note: While most chemical soil additives are non-toxic, some compounds constitute serious hazards. State, federal, and in some cases, local controls regulate the handling and labeling of toxic additives. Laws also affect labeling procedures with respect to guaranteed analysis and, where appropriate, physical properties. The instructor should attempt to assemble and outline the laws and regulations that are applicable.

1. The need for laws and controls in the field of soil additives

    a. Background, early laws, and controls

2. Provisions of the laws, controls, and regulatory acts pertaining to the manufacture, sale, and use of chemicals as soil additives

    a. Federal

    b. State

    c. Local

Suggested Teaching-Learning Activities

1. Ask a lawyer in the community to speak to the class concerning laws, regulations, and controls which apply to agricultural chemicals. A case study type of approach may be desirable.

2. Write to and obtain copies from your local congressman of specific laws that apply to soil additives.

3. Divide the class into teams. Have them visit local firms in the agricultural chemicals retail business to determine controls and regulations which are printed on the containers of soil additives.

4. Design a chart which summarizes laws, regulations, and controls affecting the sale and use of chemicals for use as soil additives.

Suggested Instructional Materials and References

1. Instructional Materials

   a. Copies of laws and regulations obtained from congressman and local authorities.

   b. Chart summarizing laws, regulations, and controls.

2. References

   a. Pub. Law 518 - 83rd Congress, Chapter 559 - 2nd Session J. R. 7125, Federal Food, Drug and Cosmetic Act Amendment (Miller).

   b. Federal Insecticide, Fungicide, and Rodenticide Act of 1947.

   c. <u>Open Door to Plenty</u>, a bulletin, National Agricultural Chemical Association, 1145 19th Street, N.W., Washington, D.C.

Suggested Occupational Experience

Schedule the class for a visit to a court session involving agricultural chemicals. If this is not possible, develop a role-playing type of approach with a farmer, lawyer, judge, and typical courtroom scene being played by members of the class. Emphasize, in either experience, the role of the agricultural chemical technician.

IV. <u>To learn to recognize and identify various soil conditions of structure and/or the chemical composition which has been impaired, altered, or damaged, and to gain an understanding of the factors affecting these changes.</u>

Teacher Preparation

Subject Matter Content

Note: Requisite to planning a soil improvement program is the ability to accurately identify the various factors, both in and out of the soil, which influence soil productivity and then to be able to ascertain whether or not for a given soil, these factors are present within minimum acceptable standards. Local conditions and student interests may determine the depth to which these topics are pursued.

1. Review factors which influence soil productivity and crop adaptation

   a. Climate

      1) Length of growing season

      2) Seasonal temperatures

      3) Plant competition

      4) Species and varieties of plants

2. Soil acidity

   a. Soil acidity has been defined as the lack of chemical bases. It is common in regions where precipitation is sufficiently high to leach appreciable amounts of exchangeable bases from the upper layers of soils. Acidity is expressed in pH, the logarithm of the reciprocal of the hydrogen ion (H^+) concentration. The pH scale is 0 to 14 and 7 indicates neutral reaction or equal concentrations of H^+ and OH^-. A solution of pH6 has 10 times as many hydrogen ions as one of pH7. By definition, an acid soil is one having a pH of less than 7; however, soils ranging from 6.7 to 7.3 are often regarded as being neutral. A pH lower than 4 is found in few soils and pH in excess of 10.5 is seldom found in soils.

   Two types of soil acidity exist, i.e., reserve, potential, or exchangeable soil acidity and that known as active acidity. The latter results from the excess of H ions in

solution surrounding the soil colloidal complex. These dissociated H ions are in equilibrium with those absorbed on the complex. When leaching or neutralization of the active H ions occurs, more ions dissociate from the complex to restore the equilibrium. Those ions on the complex constitute reserve soil acidity. The active acidity represents only a small portion of the total supply of H ions. Soils high in colloidal materials (clay and organic matter) are very resistant to changes in pH. They are regarded as being highly "buffered" and generally require greater amounts of additives for pH changes.

b. Methods of determining soil acidity

1) Electrometric method

a) The pH meter is regarded as the most accurate device

2) Dye methods

a) Use of indicators, accurate within $\pm$ 1.5%

It should be noted that pH figures represent only average values for soil samples. Considerable variation may occur from one spot to another in the field, and the difference in acidity between the capillary films (low) and the colloidal interfaces (high) can be considerable.

c. Distribution of acid soils in the United States

Acid soils develop most rapidly in areas where rainfall is sufficiently abundant to leach away bases liberated by ionic exchange and mineral decomposition. Most of the acid soils in this country are east of Omaha, Nebraska. They also occur in local areas of the West, especially in the high rainfall regions of Washington and Oregon. Within the regions containing acid soils, sizable acreages are well supplied with bases. This is particularly true in parts of the tall-grass prairie, in young soils derived from limestone and glacial till, and in young soils developing on poorly drained locations and recently exposed lake beds. However, most soils, including muck and peat, throughout the East respond to lime.

d. Factors that contribute to soil acidity

1) Climate

a) Excess rainfall and leaching

b) Temperature

2) Parent soil materials

a) Acid rocks

(1) Excess of quartz or silica in relation to the content of basic minerals or elements.

(2) Examples - granite and rhyolite.

(3) Many acid sandy soils developed from acid rocks.

b) Sand - producing parent materials.

(1) Because of the high permeability and relatively low exchange capacity of sandy soils, they tend to become acid before fine-textured soils.

3) Vegetation and microorganisms

a) Liberation of CO_2 from roots - gives rise to formation of hydrogen and bicarbonate ions.
$CO_2 + HOH \rightarrow HCO_3^- + H^+$

(1) Replacement of bases by H^+ and subsequent loss of some bases.

4) Farm practices and problems

a) Exposed and unprotected soil.

(1) Leaching generally increases when virgin lands are tilled.

b) Removal of plant and crop materials reduces supply of exchangeable bases (up to 100 and more pounds of calcium carbonate per acre).

c) Fall plowing may increase leaching rate.

d) Certain commercial fertilizers develop mineral acids and result in a loss of bases.

(1) Ammonium sulfate.

(2) Ammonium nitrate (surface layer).

3. Nonsaline-alkali soils

a. Description

1) High percentage (more than 15) of the total exchange capacity is exchangeable sodium.

2) Conductivity of the saturation extract is less than 4 mmhos/cm. at 25° C.

a) Concentration of neutral soluble salts is usually. low.

3) The pH readings are high, usually between 8.5 and 10.

a) Exchangeable sodium is free to hydrolyze; will become associated with clay particles in soil.

4) Soils which tend to be deflocculated and impermeable are often known as "slick spots." They are difficult to till.

5) Also called "black alkali," because dispersed and dissolved organic matter frequently is deposited on the surface.

6) In time, the dispersed clay may migrate downward, forming a very dense layer having a prismatic or columnar structure. The surface soil may become relatively coarse in texture and friable.

Note: An alkaline soil is one having an alkaline reaction, i.e., a pH reading in excess of 7.0 (or for practical purposes, 7.3). The soil solutions of non-saline-alkali soils usually contain small amounts of calcium and magnesium, and large amounts of sodium. The anions consist primarily of chloride, sulfate, and bicarbonate, and frequently small amounts of normal carbonate. In the presence of carbonate ions and at high pH readings, calcium and magnesium are precipitated; therefore, the soil solutions usually contain only small amounts of these cations, sodium being the predominant one. In some areas large quantities of potassium salts also may occur in these soils. Occasionally "degraded alkali" soils are found which in the surface layers may have pH readings as low as 6. They occur only in the absence of lime and the relatively low pH values result from exchangeable hydrogen.

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*See page 6 of U.S.D.A. Handbook No. 60.

b. Methods of determining and diagnosing alkalinity and salinity

Note: The instructor should attempt, at this point, to become acquainted with the methods of determining and/or evaluating salinity, as well as alkalinity. They are interrelated and the methods are involved in the diagnosis of the three types of halomorphic soils. The methods are described in detail in the U.S.D.A. Handbook No. 30, pages 7-33 and 83-126. Additional information may be obtained from state and local extension offices and experiment stations.

1) Soil sampling procedure

a) Depth

(1) Criteria for determining

b) Size

c) Number and field location

2) Estimates of soluble salts from electrical conductivity

a) Saturated soil paste

b) Soil-water extracts

(1) Saturation extract

(2) Twice-saturation extract for coarse textured soils

(3) Soil-water extracts at 1:1 and 1:5

(4) Soil extract in the field-moisture range

c) Electrical conductivity of solutions

(1) Standard wheatstone bridge

(2) Direct indicating bridge

d) Conversion of conductivity data to a standard reference temperature

e) Comparison of per cent salt in soil and extract measurements

f) Resistance of soil paste and per cent salt in soil

3) Freezing-point depression

4) Chemical determinations

a) Soil reaction - pH

b) Soluble cations and anions

c) Exchangeable cations

d) Gypsum

e) Lime

5) Physical determinations

a) Infiltration rate

b) Permeability and hydraulic conductivity

c) Moisture retention by soil

d) Density and porosity

e) Aggregation and stability of structure

f) Modulus of rupture - extent of crust formation

6) Choice of determinations and interpretation of data. The instructor of classes where halamorphic soils are of considerable interest and concern should review carefully pages 25-33 of Agriculture Handbook 60.

c. Distribution of nonsaline-alkali soils in the U. S.

1) Seventeen Western States

a) Arid and semi-arid regions

b) Irrigated soils

c) Non-irrigated areas

d. Natural factors that contribute to alkalization or the accumulation of exchangeable sodium in soils

A brief review of cation exchange and adsorption should prove beneficial.

1) Climate

a) Rainfall - insufficient to provide for removal of salts formed during mineral decomposition

b) Temperature and relative humidity

(1) Evaporation rate

2) Inadequate drainage

a) Subsurface

(1) High water table

(2) "Hard pan" or impervious layers

(3) Soils having low permeabilities

b) Surface

3) Excess soluble salts in water

a) Natural surface water

b) Ground water

(1) Salt content dependent upon rocks and soils involved*

e. Factors related to farm management practices that contribute to alkalization of soils

1) Excessive irrigation

a) High water tables - especially in "low lands"

2) Seepage from irrigation systems - raised water tables

3) Use of irrigation water having high salt contents, especially when drainage is poor and leaching is insufficient

4) High sodium content in irrigation water, and resulting sodium impregnation of soil colloids

a) Deflocculation or colloidal dispers : resulting in reduced permeability

5) Failure to provide adequate drainage of irrigated lands

*Review sources of salts in U.S.D.A. Handbook No. 30, page 3.

4. Saline Soils

a. Description

1) Soils containing natural soluble salts in concentrations sufficient to be detrimental to plant growth.

2) Conductivity of the saturation extract is more than 4 mmhos/cm. at 25° C.

3) Sodium ions constitute less than 15 per cent of the cation exchange capacity. Sodium seldom comprises more than half of the soluble cations and is not adsorbed in significant amounts.

4) The pH is usually less than 8.5.

a) Soluble salts are usually neutral and consist largely of chlorides and sulfates of calcium, magnesium, and sodium. Some bicarbonates and nitrates also may be present.

5) Saline soils generally are flocculated and relatively permeable.

a) Excess salts and moderate to low amount of exchangeable sodium.

6) White crusts frequently found on the surface; also called "white alkali" soils.

b. Methods of determining and diagnosing salinity

The instructor should refer to section B on page 28 for an outline of applicable methods.

c. Distribution of saline soils in the U. S.

1) Seventeen Western States

a) Arid and semi-arid regions

b) Irrigated soils (of principle economic importance)

c) Non-irrigated soils

d. Factors that contribute to salinization of soils

Note: The principal factors leading to and causing salinity are much the same as those presented for alkalization. They need not be repeated here in detail, but a brief outline may afford a beneficial review.

1) Natural

a) Climate

(1) Rainfall

(2) Temperature and relative humidity

b) Inadequate drainage

(1) Subsurface

(2) Surface

c) Excess soluble salts in water

2) Farm management

a) Excessive irrigation

b) Seepage from irrigation systems

c) Use of irrigation water having high salt content

d) Failure to provide adequate drainage of irrigated lands

5. Saline-alkali soils

These soils are formed from the combined processes of salinization and alkalization. They are characterized by a high concentration of soluble salts (conductivity of the saturation extract greater than 4 mmhos/cm. at 25° C), and a high percentage of exchangeable sodium (greater than 15%). As long as excess salts remain, the appearance and characteristics of these soils generally are similar to those of saline soils. The pH is usually under 8.5. However, if the soluble salts are leached downward the pH may rise above 8.5, the sodium causes colloidal dispersal, and an unfavorable structure results. The movement of soluble salts back into the surface soil may restore such a soil to its previous condition and properties.

Note: The general distribution of saline-alkali soils, the methods of diagnosing them, and the factors associated with their development are essentially the same as those presented for the two other types of halomorphic soils. The instructor may refer freely to the previous sections.

6. Compacted, crusted, and impervious soil conditions

Compaction, crusting, and slow water penetration are conditions associated primarily with fine textured soils having an unfavorable structure or aggregation of soil particles. While

found in virgin soils, these conditions frequently result from the adverse effects of improper tillage and cropping practices on soil structure. The impervious soil conditions associated with alkalinity and salinity will have been discussed in the previous sections.

The instructor should review the factors affecting soil granulation or aggregation. Factors which tend to reduce aggregation, resulting in soil impairment may be listed as follows:

a. Inadequate soil surface protection

   1) Mechanical beating of rain

   2) Puddling

   3) Excessive run off and loss of organic matter

b. Excessive tillage

   1) Increased rate of oxidation of organic matter

   2) Compression of aggregates and increased bulk density

   3) Breakdown of stable aggregates

c. Improper tillage

   1) Soil too wet or too dry

   2) Improper implement with respect to climatic or soil conditions

d. Reduced organic matter content

   1) Heavy cropping and insufficient return of plant residues to soil

   2) High temperatures

Many soils throughout the country exhibit crusting, compaction, and inadequate infiltration rates. This is especially true of the fine-textured soils, except where highly stable granulation exists. Under intensive cultivation these soil impairments have become more pronounced. For example, the structure of over two million acres in California has deteriorated sufficiently to be of economic significance.

Suggested Teaching-Learning Activities

1. Take a field trip to evaluate various soil conditions. Have the class collect soil samples for laboratory use in determining the need for soil additives. Samples of crops growing on the fields should also be collected by the class during the field trip for laboratory purposes.

2. Have the class build a model for demonstrating acidity, alkalinity, salinity, and various plant growth conditions.

3. Ask your soil conservationist to speak concerning "Effect of Soil Conditions on Plant Growth Where Soil Structure or Composition Has Been Impaired."

4. Conduct an exercise on field recognition of conditions studied in this unit.

Suggested Instructional Materials and References

1. Instructional Materials

   a. Soil samples

   b. Lab equipment

   c. Material for constructing model

2. References

   a. Land Judging Bulletin or similar type bulletin from State Extension Service.

   b. Soils, 1957 Yearbook of Agriculture.

   c. Soil Science, Millar, Turk. John Wiley & Sons, Inc., New York New York.

   d. Diagnosis and Improvement of Saline and Alkali-Soils, U. S. Salinity Laboratory Staff, U.S.D.A. Handbook No. 60 (Price $2).

   e. The Nature and Properties of Soils, 6th Edition, Buckman & Brady, The Macmillan Company, New York.

   f. Soil Conditions and Plant Growth, 9th Edition, Russel. John Wiley & Sons, Inc., New York.

g. Soil Management for Conservation and Production, Cook. John Wiley & Sons, Inc., New York, New York.

h. Irrigated Soils, Thorne and Peterson, Blakeston, 1954, Philadelphia and Toronto.

Suggested Occupational Experience

Arrange for the students to accompany an agricultural chemical technician while making a farm visit to determine the need for soil additives. It may be advisable to accomplish this during summer co-operative experience programs.

V. To become knowledgeable, at the technical level, regarding various chemicals which are commonly used as soil additives.

Teacher Preparation

Subject Matter Content

Note: A high level of competency in this field is dependent upon an understanding of the technical aspects of various chemicals available for use as soil additives.

1. Properties and characteristics of additives for use on acid soils

Note: The standard amendment or additive used on acid soils is lime. In isolated cases it is desirable to intensify the acidity of soils. This is primarily for the culture of ornamentals and the reduction of potato scab infestation Among the additives used in these cases are ferrous sulfate and flowers of sulfur. Ammonium sulfate also is relatively effective in lowering soil pH.

a. Forms of lime

(From a strict chemical standpoint, there is only one compound referred to as lime, calcium oxide. In agriculture the term has a broader meaning; it includes all compounds of calcium and magnesium used to raise the pH of soils.)

1) Oxide of lime

a) Known as burned lime, quicklime, or oxide

b) Essential reactions in production

$$CaCO_3 + \text{Heat} \rightarrow CaO + CO_2$$

$$CaMg(CO_3)_2 + \text{Heat} \rightarrow CaO + MgO + CO_2$$

Ratio of CaO to MgO = 4 or 5:1

c) Purity

Ranges from 85 to 98%, calcium and magnesium oxides predominate.

Small amounts of hydroxides and some inert impurities are also present.

d) Highly caustic and disagreeable to handle

e) Usually pulverized and bagged

2) Hydroxide of lime

a) Known as slaked lime, caustic lime, hydrated lime, hydrate, agricultural hydrate, and water-slaked lime

b) Reaction in production

$$CaO + H_2O \rightarrow Ca(OH)_2$$

$$MgO + H_2O \rightarrow Mg(OH)_2$$

c) Purity

May range as high as 95%, impurities similar to those in the oxide form. Volume much greater after slaking.

3) Carbonate of lime

a) Several lime compounds are sold as carbonate of lime

-- Ground limestone

-- Marl or bag limestone

-- Oyster shells

b) Principle compounds

-- Calcium carbonate ($CaCO_3$)

-- Dolomite $CaMg(CO_3)_2$

(When little or no dolomite is present, limestone is called calcic, as the magnesium content increases it becomes dolomite limestone, and if little calcium carbonate is present - dolomite.)

c) Most ground limestone is of calcic and dolomite limestone (dolomitic) and the purity ranges from 75 to 95 per cent. The average may be about 94 per cent.

b. Chemical guarantee

The relative neutralizing power of different forms of lime are listed below.

Form of lime	Molecular Weight	Neutralizing value %	Pounds Equivalent to 1 ton of pure $CaCO_3$
Calcium carbonate	100	100	2,000
Magnesium carbonate	84	119	1,680
Calcium hydroxide	74	135	1,480
Magnesium hydroxide	58	172	1,160
Calcium oxide	56	178	1,120
Magnesium oxide	40	250	800

There are various methods used in describing the chemical composition or equivalent and of designating the chemical guarantee. Several states have laws regulating the labeling and sale of commercial lime materials. The laws are not uniform with respect to the methods of expressing guarantees. It is recommended that the instructor solicit the aid of local extension and commercial soils specialists in presenting information regarding chemical guarantees.

c. Fineness guarantee

Fineness is guaranteed on the basis of mechanical analysis of samples. Components of the samples are separated by the use of standard screens, and the percentage, by weight, that pass through each screen is tested. The finer the stone is ground, the more rapidly it dissolves, also the greater the cost. Many soil specialists recommend the application of medium-ground lime. It generally contains a sufficient array of stone size to provide for relatively rapid results as well as a prolonged neutralization. Such an array or grind would all pass through an 8-mesh screen (8 openings/square inch) and of which 25 to 50% would pass through a 100-mesh screen. The instructor may consult additional source materials, such as those presented in Section II, for supplemental information on chemical and physical analyses.

d. Costs

The costs of lime in its various forms will be conditioned by such things as (a) purity, (b) fineness, (c) chemical composition, and (d) transportation costs.

Approximate costs of the available forms of the common grades or fineness should be readily available to the instructor.

2. Properties and characteristics of additives for use on alkali soils.*

Note: Reclamation of both types of alkali soil, nonsaline-alkali and saline-alkali, involves the replacing of exchangeable sodium with calcium. Three general types of additives are used:

Types of Additives	Chemicals
Soluble calcium salts	Calcium chloride
	Gypsum
Acids or acid formers	Sulfur
	Sulfuric acid
	Iron sulfate
	Aluminum sulfate
	Lime-sulfur
Calcium salts of low solubility	Ground limestone
(May also contain magnesium)	By-product lime from sugar factories

a. The instructor will determine which chemicals are to be studied in detail. The selection will depend, of course, upon the requirements of local areas and situations. Among the properties and characteristics which may be considered are:

1) Chemical name (active ingredient)

*The reclamation of saline soils <u>normally</u> involves leaching and probably improved drainages but not additives.

2) Empirical formula

3) Common names

4) Trade names

5) Solubilities

6) Odor

7) Color

8) Density

9) Physical state (liquid, solid)

10) Corrosive action

11) Stability

12) Concentration

13) Purities/grades

14) Industrial preparation

15) Phytotoxicity

16) Toxicity

17) Special hazards

18) Antidotes and first aid

19) Factors which limit the effectiveness of the chemical (such as temperature, sunlight, water, etc).

3. Properties and characteristics of additives for use in reducing soil crusting and/or loss of permeability.

Note: Chemical additives have been applied to compacted soils or to those which do not have satisfactory particle aggregation. The prime objective has been to enlarge the pore space by providing increased binding of the fine soil particles into aggregates. Some of the chemicals that have been used are listed below:

VAMA - a copolymer of vinyl acetate and malic acid

IBMA - the half amide, ammonium salt of isobutylenemaleic acid, anhydride copolymer

TPS-CL - Triphenysulfonium chloride

Ferric sulfate

a. The instructor should determine which of the additives listed and which of the probable new chemicals should receive careful study. The usage and value of the available additives will depend largely upon the soils and agriculture of the area. (At this point, December 1965, they have received considerable attention, but rather limited use.) From the preceding list of properties and characteristics, the instructor should select those which are most applicable to the additives studied in this section.

Suggested Teaching-Learning Activities

1. Develop laboratory experiments which involve chemicals that are used as soil additives. Have each student run the experiment and observe the reactions.

2. Divide the class into three groups. Ask each group to design, discuss, and demonstrate an experiment showing reactions involved in acidity, alkalinity, or salinity.

3. Collect various samples.

4. If possible, arrange a field trip to one or more chemical plants in which several of the additives discussed are being processed, formulated, and/or packaged. Permit the students to visit with company representatives and to discuss with them items such as processing, sources of raw materials, handling of additives, safety precautions, costs, and local usage.

Suggested Instructional Materials and References

1. Instructional Materials

   a. Samples of acid, saline, and alkali soils (these may be from the field or modified in the laboratory).

   b. Appropriate chemicals and laboratory equipment.

2. References

   a. Land Judging Bulletins or similar type of bulletins from State Extension Service.

   b. Soils, 1957 Yearbook of Agriculture.

   c. Soil Science, Millar, Turk. John Wiley & Sons, Inc., New York, New York.

   d. Diagnosis and Improvement of Saline and Alkali-Soils, U. S. Salinity Laboratory Staff, U.S.D.A. Handbook No. 60 (Price $2).

e. <u>The Nature and Properties of Soils</u>, 6th Edition, Buckman & Brady. The Macmillan Company, New York, New York.

f. <u>Soil Conditions and Plant Growth</u>, 9th Edition, Russel. John Wiley & Sons, Inc., New York, New York.

g. <u>Soil Management for Conservation and Production</u>, Cook. John Wiley & Sons, Inc., New York, New York.

h. <u>Irrigated Soils</u>, Thorne and Peterson. Blakeston, 1954, Philadelphia and Toronto.

i. Pugh, A. L., et al. "Modification of Some Physical Characteristics of Soils With VAMA, Ferric Sulfate, and Triphenylsulfanium Chloride." Agran. J. 52:399-402, 1960.

j. Taylor, H. M. and Vomocil, J. A. "Changes in Soil Compressibility Associated With Polyelectrolyte Treatment." Proceed. Soil Sci. Soc. America, Vol. 23:181-183, 1959.

k. Selected bulletins and pamphlets from state experiment stations and extension service and from local chemical company representatives.

VI. To gain a knowledge and understanding of the principles and concepts underlying the use of soil additives.

Teacher Preparation

Subject Matter Content

The technical worker should have acquired the ability to recognize various impaired soil conditions (Competency IV) and should have gained a technical knowledge concerning various soil additives (Competency V). He now should acquire a knowledge of the fundamental reactions involved in the use of chemical soil amendments. This will provide for a better understanding of the functions, benefits, and uses of soil additives.

1. Review

    a. Acid soils

    b. Saline soil

    c. Saline - alkali soils

    d. Nonsaline - alkali soils

    e. Crusted and/or compacted soils

    f. Lime forms

    g. Chemicals used in the reclamation of alkali soils

    h. Chemical anti-crustants and soil conditions

2. Principles underlying the use of soil additives

    a. Correcting undesirable acid conditions - the application of lime

        1) Effects on the soil

            a) Physical

                -- Structure tends to be improved

                -- Erosion may be reduced because of increased plant top and root growth

            b) Chemical

                -- The concentration of H^+ will decrease

                -- The concentration of OH^- will increase

-- The solubility of iron, aluminum, and manganese will decline (under very acid conditions these may be present in toxic quantities).

-- The availability of phosphates, sulfur, and molybdates will be increased.

-- The exchangeable calcium and magnesium will be augmented.

-- The base saturation and percentage will be increased.

-- Potassium availability may be increased or decreased, depending upon conditions.

-- The principle chemical reactions for calcium limes are indicated below. Initial reactions are toward the bicarbonate form.

$$CaO + H_2O \rightarrow Ca\ (OH)_2$$

$$Ca(OH)_2 + 2H_2CO_3 \rightarrow Ca\ (HCO)_2 + 2H_2O$$

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2$$

Reactions with the soil colloids may be generalized as follows:

$$\underset{H}{H}\boxed{\quad} + Ca(OH)_2 \rightleftharpoons Ca\boxed{\quad} + 2H_2O$$

$$\underset{H}{H}\boxed{\quad} + \underset{\text{(in solution)}}{Ca(HCO_3)_2} \rightleftharpoons Ca\boxed{\quad} + 2H_2O + CO_2\uparrow$$

$$\underset{H}{H}\boxed{\quad} + \underset{\text{(solid)}}{CaCO_3} \rightleftharpoons Ca\boxed{\quad} + H_2O + CO_2\uparrow$$

Reactions involved could be generalized in the same fashion. In both cases CO_2 is evolved freely and calcium and magnesium are absorbed to raise the percentage base saturation.

Note: When calcium and magnesium are supplied in limestone of average fineness, three forms thereof will

exist in the soil for a time. They are: (1) solid calcium and calcium-magnesium carbonates, (2) exchangeable bases absorbed by the colloidal matter, and (3) cations in the soil solution mostly in association with bicarbonate ions.

c) Biological

-- Microbial activity is stimulated

-- Nitrification rate is increased

-- Nitrogen fixation is enhanced

2) Crop response to liming

(It may be advisable for the instructor to show and discuss one of many charts available which indicate the levels of lime or pH to which many crops appear best adapted.)

Favorable crop response may result from:

a) Benefits of increased supply of calcium and magnesium

b) Increased availability of certain elements

c) Removal or neutralization of toxic compounds

d) Retardation of some plant diseases

e) Increased microbial activity

3) Overliming

On light or sandy soils caution may be required to prevent overliming. Lime applications in excess of those required to raise the pH to the desired levels can be detrimental.

a) Deficiencies of available iron, manganese, copper, or zinc may be induced.

b) Phosphorous availability may be decreased. (Formation of insoluble calcium phosphates.)

c) Boron uptake may be hindered.

d) The rise in pH may be excessive for intended crops.

Note: As indicated in Section V, in some cases it may be desirable to intensify soil acidity.

Chemical reactions applicable:

$$FeSO_4 + H_2O \rightleftharpoons H_2SO_4 + FeO$$

$$2S + 3O_2 + H_2O \rightleftharpoons 2H_2SO_4$$ (Brought about by sulfur bacteria in soil)

$$(NH_4)_2\ SO_4 + 4O_2 \rightarrow 2HNO_3 + H_2SO_4 + 2H_2O$$

$$H_2SO_4 = \underset{X}{\overset{X}{\boxed{}}} \rightarrow XSO_4 + \underset{H}{\overset{H}{\boxed{}}}$$ (Replacement of basic elements in soil colloids by H^+)

b. Additives used in the reclamation of alkali soils

Note: Depending upon the apparent needs and interests of the class, the instructor may find it desirable to make a careful study of portions of the U.S.D.A. Handbook No. 60, especially Chapter III. That section is an excellent source of information for those who may be required to assist in the reclamation of alkali soils. In order for them to provide effective assistance they should understand the mode of action of appropriate additives within various soils and important principles and practices regarding the teaching of halomorphic soils.

1) Chemical reactions of various additives in alkali soils.

The chemical equations illustrate the principal manner in which several additives react in three classes of alkali soils. In these equations the letter "X" represents the soil complex or particle.

Class 1. Soils containing alkaline-earth carbonates.

Gypsum. $2NaX + CaSO_4 \rightleftharpoons CaX_2 + Na_2SO_4$

Sulfur. (1) $2S + 3O_2 \rightleftharpoons 2SO_3$ (Induce by sulfur bacteria)

(2) $SO_3 + H_2O \rightleftharpoons H_2SO_4$

(3) $H_2SO_4 + CaCO_3 \rightleftharpoons CaSO_4 + CO_2 + CO_2 + H_2O$

(4) $2NaX + CaSO_4 \rightleftharpoons CaX_2 + Na_2SO_4$

Lime-sulfur. (Calcium polysulfide)

(1) $CaS_5 + 8O_2 + 4H_2O \rightleftharpoons CaSO_4 + 4H_2SO_4$

(2) $H_2SO_4 + CaCO_3 \rightleftharpoons CaSO_4 + CO_2 + H_2O$

(3) $2NaX + CaSO_4 \rightleftharpoons CaX_2 + Na_2SO_4$

Iron Sulfate.

(1) $FeSO_4 + H_2O \rightleftharpoons H_2SO_4 + FeO$

(2) $H_2SO_4 + CaCO_3 \rightleftharpoons CaSO_4 + CO_2 + H_2O$

(3) $2NaX + CaSO_4 \rightleftharpoons CaX_2 + Na_2SO_4$

Class 2. Soils containing no alkaline-earth carbonates, pH 7.5 or higher.

Gypsum. Same as in class 1.

Sulfur. Steps (1) and (2) as in class 1.

(3) $2NaX + H_2SO_4 \rightleftharpoons 2HX + Na_2SO_4$

Lime-sulfur. Step (1) as in class 1.

(2) $10NaX + H_2SO_4 + CaSO_4 \rightleftharpoons 8HX + CaX_2 + 5\ Na_2SO_4$

Iron sulfate. Step (1) as in class 1.

(2) $2NaX + H_2SO_4 \rightleftharpoons 2HX + H_2SO_4$

Limestone. Two possibilities have suggested

$$2NaX + CaCO_3 \rightleftharpoons CaX_2 + Na_2CO_3$$

and

(1) $NaX + HOH \rightleftharpoons NaOH + HX$

(2) $2HX + CaCO_3 \rightleftharpoons CaX + CO_2 + H_2O$

Class 3. Soils containing no alkaline-earth carbonates, pH less than 7.5 (not common).

<u>Gypsum</u>. Same as in class 1 and 2.

<u>Sulfur</u>. Same as in class 2.

<u>Lime-sulfur</u>. Same as in class 2.

<u>Iron sulfate</u>. Same as in class 2.

<u>Limestone</u>. Same as in class 2, and if exchangeable hydrogen is present:

$$(1)\quad 2HX + CaCO_3 \rightleftharpoons CaX_2 + CO_2 + H_2O$$

2) Effects of additives on soils (assuming accompanying reclamation procedures, e.g., drainage and leaching).

a) Physical

-- Structure tends to be improved (or at least maintained if saline-alkali soils are involved).

-- Permeability tends to be improved.

-- Drainage tends to be improved.

b) Chemical

-- The concentration of exchangeable Na^+ will decrease.

-- The concentration of exchangeable Ca^{++} will increase.

-- The pH level tends to be reduced, especially in nonsaline-alkali soils.

-- The salt concentration tends to be reduced.

-- Nutrient availability tends to be improved.

c. Correcting or preventing undesirable soil structure.

1) Mode of action within the soil

a) Binding or cementing action

b) Stabilizing properties

2) Effects of additives on soils

a) Physical

-- Structure

-- Permeability

-- Drainage

b) Chemical

-- Nutrient availability

-- Buffering action (if any)

3) Persistency within the soil

4) Influence of tillage practices on additive effectiveness.

d. Correcting or preventing undesirable soil structure.

Note: The outline presented under paragraph 3 may be repeated here, or the instructor may wish to present the information applicable to these two paragraphs as one unit.

3. Application of soil additives - form, rate, time, and methods.

a. Lime

1) Initial practical considerations

a) Crops to be grown

b) Probable value of liming

2) Form of lime to be used

a) Desired time of crop response

b) Rates of reaction with the soil

c) Chemical guarantees

d) Costs

e) Fineness guarantees

f) Other considerations (equipment, handling, storage, packaging, etc.).

3) Application rates

Note: Fertilizer companies and experiment stations have prepared tables which suggest possible rates of lime to be applied to change the pH of representative soils to specific levels along the reaction scale. These represent estimates only, and they must be modified or viewed in terms of various factors and considerations.

a) Soil reaction, pH

-- Provides only a relative indication

b) Texture and structure of the soil

c) Nature of the clay particles

d) Buffer capacity

e) Degree of base saturation

f) Subsoil lime content

g) Crops to be grown

h) Form and fineness of the lime

i) Length of the rotation

j) Experience

4) Time of application

a) Place in rotation

-- Apply with or ahead of crop that gives most satisfactory response.

-- Many farmers apply lime 1 to 2 years before a legume crop is seeded.

b) Application can be most anytime fields are in satisfactory condition.

-- It may be desirable to apply lime just prior to annual plowing or before seedbed preparation and after plowing.

5) Method of application

   a) Large bulk spreading trucks (most common)

      -- Traverse conveyor spreaders

      -- Spinner spreaders

   b) Fertilizer drills

   c) Row applicators

6) Lime mixing or incorporation with the soil

   a) Local recommendations

   b) Rotation

   c) Soil

   d) Equipment

b. Additives for exchangeable-sodium replacement

1) Initial practical considerations

   a) Crops to be grown

   b) Potential productivity of the soil

   c) Quality and availability of irrigation water

   d) Properties of surface and subsoils

2) Additives to be used

   a) Time required for reaction in the soil

      -- Calcium chloride is quick acting, but expensive

      -- Sulfuric acid and iron sulfates also fast acting. The former may be sufficiently inexpensive for field use.

      -- Gypsum and sulfur may be the most practical and are the most commonly used. Their speed of reaction depends upon several factors.

      -- Lime - sulfur - reaction similar to that of sulfur

b) Costs

c) Fineness guarantees

d) Soil reaction

e) Nature and composition of soluble salts in the soil

3) Application rates

a) Exchangeable sodium and cation-exchange-capacity. (Tables are available which indicate equivalent amounts of various additives required for the replacement of specified amounts of exchangeable sodium.)

b) Other methods of determining the additive requirements are available. The instructor will profit by consulting the U.S.D.A. Handbook No. 60 and Irrigated Soils, by Thorne and Peterson.

c) Irrigation water quality

d) Soil depth to be amended

4) Time of application

a) Soil permeability. (Under some conditions, if leaching will not result in decreased permeability the efficiency of additives may be increased by pre-application leaching.)

b) Availability of water

c) Soil moisture

5) Method of application

a) Broadcast

-- Trucks, bulk-spreading

-- Fertilizer drill

b) Irrigation water application

6) Mixing or incorporation with the soil

a) Local recommendations

b) Soil

c) Equipment

c. Additives used in correcting or preventing undesirable soil structure.

1) Initial practical considerations

a) Crops to be grown

b) Probable value from additives

c) Equipment

2) Additives to be used

a) Soil

-- Texture

-- Organic matter

-- Types of clay

-- Structure

b) Demonstrated responses of different additives under specific soil conditions

c) Costs

3) Application rates

a) Soil properties

b) Crops

c) Costs

4) Time and method of application

a) Local recommendations

b) Cropping system

c) Equipment

d) Soil and climatic conditions

d. Additives used in correcting or preventing soil crusting. (This topic may be treated in a fashion similar to paragraph 3 or simultaneously with that subsection.)

Selected Teaching-Learning Activities

1. Use selected soil samples and conduct experiments demonstrating the actions and/or function of various additives in soils. (Selections of soils, additives, and experiments will depend upon class interests and area conditions.) It may be desirable to have most of the representative and major additives tried in the laboratory, each team of students conducting and reporting separate experiments.

2. Have a local sales representative or company agriculturalist speak to the class concerning the use and value of appropriate additives.

3. Arrange for the class to visit farms or cities where additives are being used or tried. Permit them to witness the function and benefits of these chemicals to the soil and to crop production.

Suggested Instructional Material and References

1. Instructional Materials

   a. Soil samples

   b. Lab equipment

   c. Material for constructing model

2. References

   a. Land Judging Bulletin or similar type bulletin from State Extension Service.

   b. Soils, 1957 Yearbook of Agriculture.

   c. Soil Science, Millar. Turk, John Wiley & Sons, Inc., New York, New York.

   d. Diagnosis and Improvement of Saline and Alkali-Soils, U. S. Salinity Laboratory Staff, U.S.D.A. Handbook No. 60 (Price $2).

   e. The Nature and Properties of Soils, 6th Edition, Buckman & Brady. The Macmillan Company, New York, New York.

   f. Soil Conditions and Plant Growth, 9th Edition, Russel. John Wiley & Sons, Inc., New York, New York.

   g. Soil Management for Conservation and Production, Cook. John Wiley & Sons, Inc., New York, New York.

   h. Irrigated Soils, Thorne and Peterson. Blakeston, 1954, Philadelphia and Toronto.

THE CENTER FOR RESEARCH AND LEADERSHIP DEVELOPMENT
IN VOCATIONAL AND TECHNICAL EDUCATION
THE OHIO STATE UNIVERSITY
980 KINNEAR ROAD
COLUMBUS, OHIO, 43212

INSTRUCTOR NOTE: As soon as you have completed teaching each module, please record your reaction on this form and return to the above address.

1. Instructor's Name_______________

2. Name of school_______________State_______________

3. Course outline used: _____Agriculture Supply--Sales and Service Occupations
_____Ornamental Horticulture--Service Occupations
_____Agricultural Machinery--Service Occupations

4. Name of module evaluated in this report_______________

5. To what group (age and/or class description) was this material presented?_____
____

6. How many students:
   a) Were enrolled in class (total) _____
   b) Participated in studying this module _____
   c) Participated in a related occupational work experience program while you taught this module _____

7. Actual time spent teaching module: Recommended time if you were to teach the module again:

Actual time spent teaching module		Recommended time if you were to teach the module again
_____hours	Classroom Instruction	_____hours
_____hours	Laboratory Experience	_____hours
_____hours	Occupational Experience (Average time for each student participating)	_____hours
_____hours	Total time	_____hours

(RESPOND TO THE FOLLOWING STATEMENTS WITH A CHECK (✓) ALONG THE LINE TO INDICATE YOUR BEST ESTIMATE.)

	VERY APPROPRIATE	NOT APPROPRIATE
8. The suggested time allotments given with this module were:		
9. The suggestions for introducing this module were:		
10. The suggested competencies to be developed were:		
11. For your particular class situation, the level of subject matter content was:		
12. The Suggested Teaching-Learning Activities were:		
13. The Suggested Instructional Materials and References were:		
14. The Suggested Occupational Experiences were:		

(OVER)

15. Was the subject matter content sufficiently detailed to enable you to develop the desired degree of competency in the student? Yes_____No_____
Comments:

16. Was the subject matter content directly related to the type of occupational experience the student received? Yes_____No_____
Comments:

17. List any subject matter items which should be added or deleted:

18. List any additional instructional materials and references which you used or think appropriate:

19. List any additional Teaching-Learning Activities which you feel were particularly successful:

20. List any additional Occupational Work Experiences you used or feel appropriate:

21. What do you see as the major strength of this module?

22. What do you see as the major weakness of this module?

23. Other comments concerning this module:

_____________________ (Date)

_____________________ (Instructor's Signature)

_____________________ (School Address)